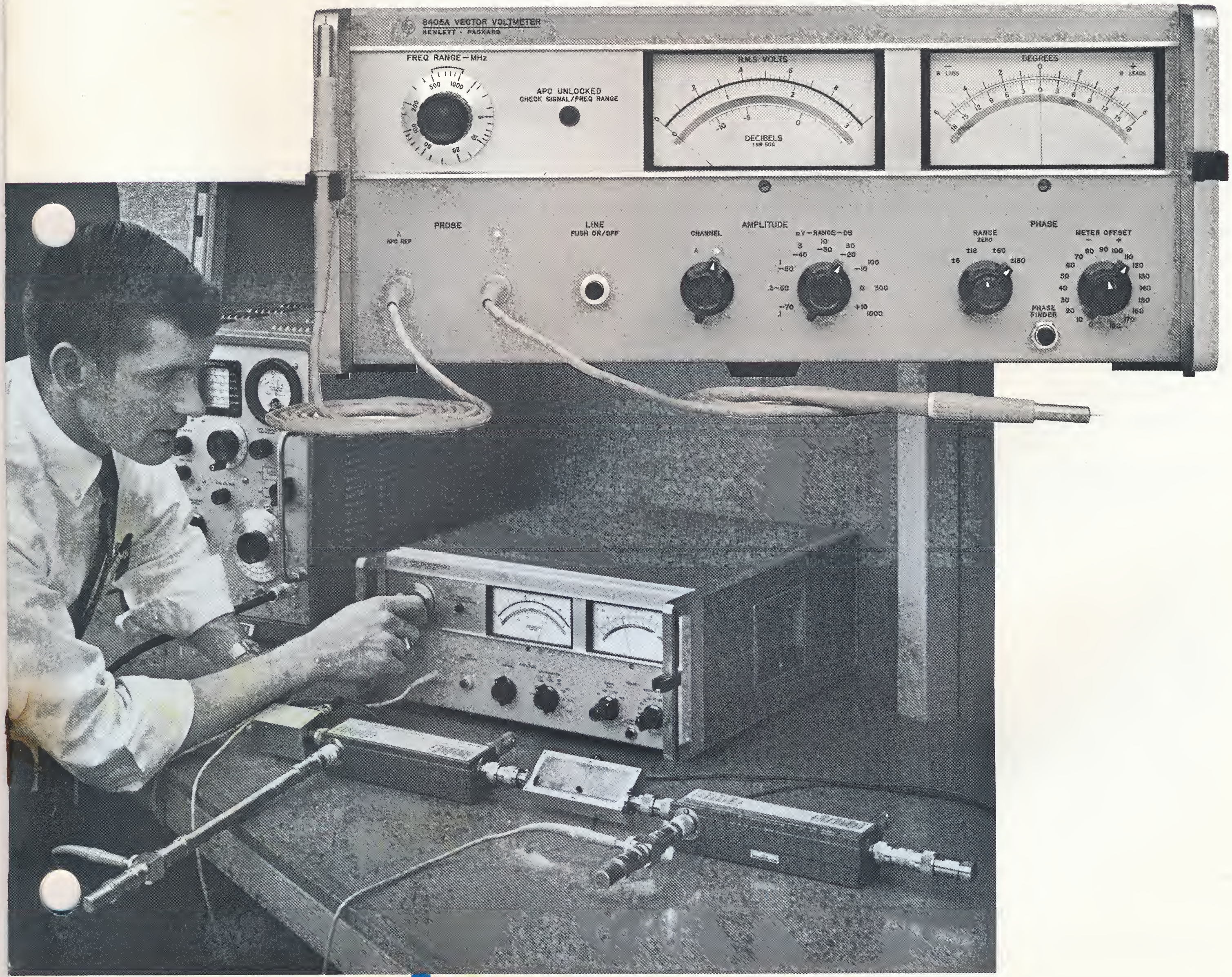
HEWLETT hp PACKARD

VECTOR VOLTMETER

model 8405A

TECHNICAL DATA 15 JUNE 66

- **Measures Phase, Amplitude from 1 MHz to 1 GHz**
- **Simplifies Component Evaluation, Circuit Design**
- **Direct Readout, Straightforward Operation**



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Printed in U.S.A.

Features

- **Complex Voltage Measurements**
  from 1 to 1,000 MHz
- **Phasemeter**
  $\pm 6°$, $\pm 18°$, $\pm 60°$, $\pm 180°$ ranges
  0.1° resolution
  $\pm 180°$ offset in 10° steps
- **Dual Channel Millivoltmeter**
  100 μvolt full-scale sensitivity
  $>$ 100-dB dynamic range
  20 kHz IF output
- **Tuned Volt/Phase Meter**
  1 kHz bandwidth
  measurement unaffected by harmonics
- **Simple Operation**
  automatic phase-locked tuning

Uses

- **Feedback circuit design**
- **Amplifier phase linearity**
- **Filter testing**
- **Cable group delay**
- **Cable length matching**
- **Complex impedance of components**
- **High-frequency transistor parameter measurements**
- **Microwave "scattering" parameters**
- **VSWR of antennas, etc.**
- **Attenuation tests**
- **Distortion measurements**
- **Amplitude modulation percentage**
- **RF leakage**
- **High-to-low frequency converter**
- **Precision frequency comparator**

New Measurement Tool

The Hewlett-Packard 8405A Vector Voltmeter provides the missing information in rf voltage measurements—PHASE. Since voltages are vector quantities having both magnitude and phase with respect to each other, simple voltage measurements tell only half the story. Much circuit design is virtually incomplete without phase information. Both voltage and phase data completely define all the network parameters needed to optimize design. The 8405A allows you to measure, in one instrument, both voltage and phase over the extremely wide frequency range of 1 to 1,000 MHz.

In addition to these unique capabilities, the 8405A features high accuracy and resolution, direct readout, and operating convenience. These features enable you to make rf voltage and phase measurements more easily than ever before. By making these measurements simple, the 8405A opens the door to new and more effective methods of component, network, and amplifier evaluation. Thus the 8405A reduces costs by minimizing equipment requirements, saves time by simplifying measurements, and increases effectiveness by extending capability over a wide frequency range.

1-kHz Bandwidth, Automatic Tuning

The 8405A is a two-channel tuned volt/phasemeter with a 1-kHz bandwidth. Thus it responds only to the fundamental frequency of the input signal, eliminating errors due to harmonics. Yet, the 8405A is as easy to operate as any untuned voltmeter, making it well suited for fast production line testing. You simply rotate a front-panel switch to select any of the 21 overlapping octave ranges which include the input signal frequency, and the automatic phase-locked tuning does the rest. To eliminate guesswork, a front-panel light tells you when the voltmeter is properly tuned. The automatic tuning will follow drifting or swept signals (up to 15 MHz/second) so long as they remain within the selected octave range.

360° Phase Range, 0.1° Resolution

Phase between the two input channels is read on a zero-center meter with end-scale ranges of $\pm 180°$, $\pm 60°$, $\pm 18°$, and $\pm 6°$. The $\pm 6°$ scale provides 0.1° resolution, and a meter offset selectable in precise 10° increments permits this resolution to be realized anywhere in the 360° range. Phase accuracy is $\pm .1°$ at fixed frequencies and constant input levels and is quite insensitive to variations in either. A push-button phase-finder switch simplifies the setting of the meter offset when the more sensitive phase ranges are selected. A DC output provides a voltage proportional to the linear phase meter for either monitoring or expanding resolution on a recorder.

Two-Channel Voltmeter, 100 µV Full-Scale Sensitivity, >100-dB Range

The two-channel input of the 8405A allows you to make repetitive voltage measurements at two points in a circuit, to check the effects of adjustments, for example, without altering the setup. Voltage is read on a single front-panel meter; you select which channel voltage is indicated simply by setting a switch.

Voltages from less than 100 microvolts to 1 volt can be measured on channel B of the 8405A, from less than 300 microvolts to 1 volt on channel A. (Channel A requires the higher input to operate the automatic tuning.) External 10:1 dividers are supplied to extend the range of both channels to 10 volts. This wide range, plus the selective 1-kHz bandwidth, enables you to measure gains or losses in excess of 100 dB simply and accurately. Both volt and phase meters have rugged, reliable taut-band suspensions with mirror-backed scales individually calibrated to the meter movement.

Applications

Complex impedance and transmission parameters. Since the 8405A measures both phase and magnitude, it can be used to fully define the complex transmission and reflection coefficient of two-port networks and components, including transistors. The simplicity of such a setup is shown in the photograph on page 1. The dual directional coupler in front of the device to be measured (in the test jig) allows both magnitude and phase of the reflection coefficient to be measured. The coupler following the device allows measurement of complex gain or attenuation. Figure 1 is a Smith-chart plot of the input reflection coefficient of a 2N3563 high-frequency transistor; the data was entered on the chart directly from the 8405A voltage and phase readings.

For straightforward impedance measurements, the 8405A is easier to use than a slotted line or vhf bridge; reducing the data involves none of the cumbersome calculations and correction factors associated with the slotted line or bridge. And the data is easily entered on a Smith chart. With a network or component fully defined, its performance under any given conditions can be determined readily.

Feedback circuit design. Design and testing of negative-feedback amplifiers is another important application for

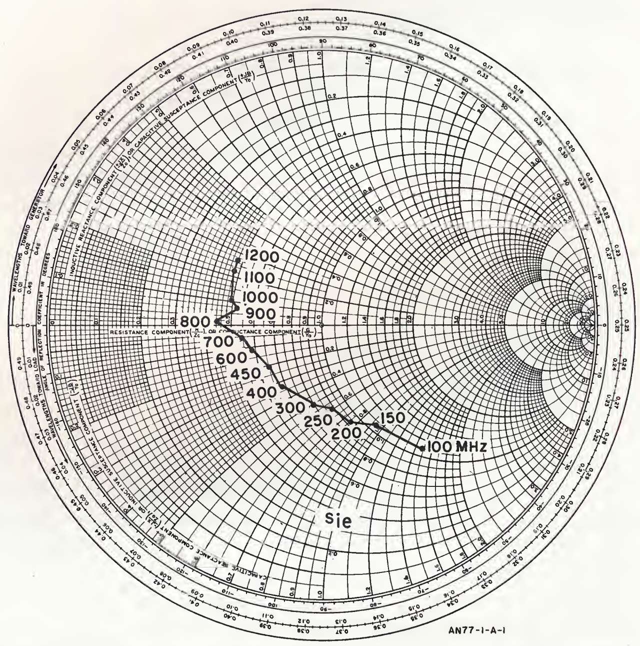


Figure 1. Input reflection coefficient for a 2N3563, common emitter configuration, from 100 to 1,200 MHz.

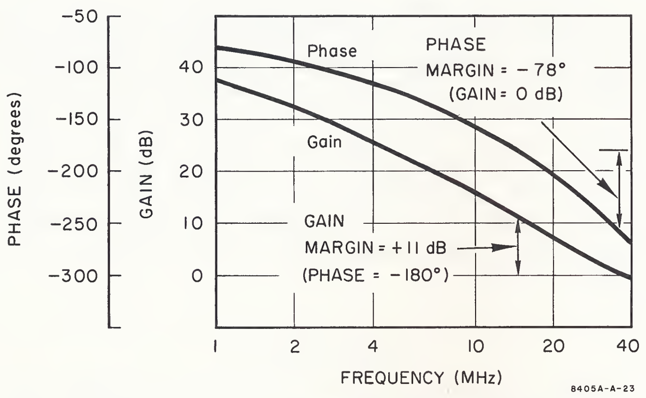


Figure 2. Open-loop gain and phase shift for a negative-feedback amplifier. As data indicates, amplifier is unstable.

the 8405A. Both phase and magnitude frequency response are measured easily. The phase margin at the gain-crossover point is readily determined, and points of marginal stability are easy to locate. Figure 2 shows data taken from an unstable amplifier. The 8405A can be used just as effectively on positive-feedback oscillators.

RF to AF converter. Because of the coherent sampling principle used in the 8405A, all rf frequencies are reconstructed at a low frequency of 20 kHz. This frequency can be observed on a low-frequency oscilloscope, wave analyzer, spectrum analyzer, etc. Modulation analysis can be performed since typical low-frequency modulation signals such as 400 Hz and 1,000 Hz are maintained on the IF output as shown in Figure 3. Thus, an inexpensive oscilloscope can read percentage AM on an rf carrier as high as 1 GHz, a wave analyzer can analyze modulation sidebands for distortion, and an audio spectrum analyzer can resolve and display narrow band modulation on an rf carrier. Since the 20-kHz output is constant and independent of the drift of the rf signal, displays are stable and jitter free.

Other uses. Many additional applications are possible, including attenuation and filter resonance and response measurements. In such measurements the wide dynamic range of the 8405A is extremely valuable. Frequency comparison is another application for which the 8405A is ideally suited. A few minutes of monitoring phase drift between two sources provides the same resolution as hours and days of direct frequency comparisons. Also, cable lengths can be measured and matched accurately through phase measurements.

These and other applications are described briefly in the *Hewlett-Packard Journal,* Vol. 17, No. 9 (May, 1966). Specific applications are covered in detail in an Application Note series. Application Note 77-1, Transistor Parameter Measurements, describes the measurement and use of "s" or scattering parameters to completely characterize a transistor. These parameters are easy to measure at frequencies up to 1 GHz with the 8405A, whereas h, y, and z parameters become difficult to work with above 100 GHz. Application Note 77-2, Precision Frequency Comparison, describes the use of phase measurements to make precise comparisons of frequency standards. Other notes in the series are presently in preparation. The Application Notes and *Journal* are available upon request from any Hewlett-Packard Field Office.

Operation

The 8405A uses the sampling technique to convert the input signals to 20-kHz replicas having the same amplitude, waveform, and phase relationship as the input signals. These 20-kHz signals are then filtered so that only 20-kHz sinusoids remain, and the amplitude of and phase difference between these sinusoids are indicated on front-panel meters. Thus, the 8405A is a tuned voltmeter which responds to the fundamental of the input signal. Voltmeter bandwidth is 1 kHz.

To maintain the converted signals at 20 kHz, the 8405A includes a phase-lock system in channel A which automatically adjusts the period between samples in both channels. In this manner the voltmeter tunes itself to the fundamental of the channel-A input signal. The automatic tuning range is selectable in overlapping bands, each covering at least an octave. Thus, the only manual tuning required is the selection of an octave range which includes the input signal. The automatic tuning not only simplifies operation but enables the 8405A to follow a slowly sweeping signal (up to 15 MHz/second) over octave bandwidths with instantaneous display of amplitude and phase. DC outputs proportional to both amplitude and phase are available on the rear panel for recording purposes.

The input signals are applied through convenient ac-coupled probes which are permanently attached to the instrument. These probes present a high input impedance (0.1 megohm shunted by 2.5 picofarads), which means that you can use them for monitoring or probing within the system under test with minimum loading effects. Accessories supplied with the voltmeter include 10:1 dividers which attach to the probes. The dividers increase the maximum voltage range to 10 volts and the input impedance to 1 megohm shunted by 2 picofarads. The ac coupling in the probes permits you to measure signals as much as 150 volts off ground.

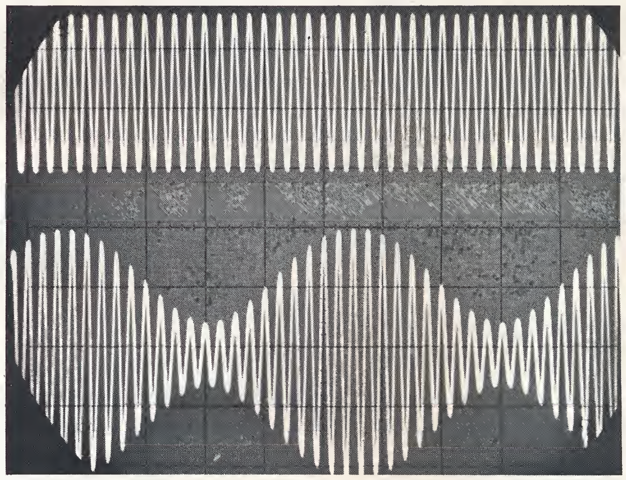


Figure 3. Reconstructed signal at 20 kHz IF Output. Input signal: 125 MHz cw (upper trace); 125 MHz cw with 1,000 Hz, 60% AM (lower trace).

Specifications

Input Characteristics

Instrument Type: Two-channel sampling rf millivoltmeter-phasemeter which measures voltage of two signals and simultaneously displays the phase angle between the two signals.

Frequency Range: 1 MHz to 1 GHz in 21 overlapping octave bands (lowest band covers two octaves).

Tuning: Automatic within each band. Automatic phase control (APC) circuit responds to the channel-A input signal. Search and lock time, approximately 10 millisec; maximum sweep speed, 15 MHz/sec.

Voltage Range:
Channel A:
1 to 10 MHz: 1.5 mV to 1 V rms;
10 to 500 MHz: 300 μV to 1 V rms;
500 to 1,000 MHz: 500 μV to 1 V rms;
can be extended by a factor of 10 with 10214A 10:1 Divider.
Channel B: 100 μV to 1 V rms full scale (input to channel A required); can be extended by a factor of 10 with 10214A 10:1 Divider.

Input Impedance (nominal): 0.1 megohm shunted by approximately 2.5 pF; 1 megohm shunted by approximately 2 pF when 10214A 10:1 Divider is used; 0.1 megohm shunted by approximately 5 pF when 10216A Isolator is used. AC coupled.

Isolation Between Channels:
1 to 400 MHz: greater than 100 dB;
400 to 1,000 MHz: greater than 75 dB.

Maximum AC Input (for proper operation): 3 V p-p (30 V p-p when 10214A 10:1 Divider is used).

Maximum DC Input: ± 150 V.

Voltmeter Characteristics

Meter Ranges: 100 μV to 1 V rms full scale in 10-dB steps. Meter indicates amplitude of the fundamental component of the input signal.

Voltage Accuracy (at the probes):
1 to 100 MHz: within ± 2% of full scale;
100 to 400 MHz: within ± 6% of full scale;
400 to 1,000 MHz: within 12% of full scale;
not including response to test-point impedance.*

Voltage Response to Test-Point Impedance:* + 0, — 2% from 25 to 1,000 ohms. Effects of test-point impedance are eliminated when 10214A 10:1 Divider or 10216A Isolator is used.

Residual Noise: Less than 10 μV as indicated on the meter.

Bandwidth: 1 kHz.

Phasemeter Characteristics

Phase Range: 360°, indicated on zero-center meter with end-scale ranges of ± 180, ± 60, ± 18, and ± 6°. Meter indicates phase difference between the fundamental components of the input signals.

Resolution: 0.1° at any phase angle.

Meter Offset: ± 180° in 10° steps.

* Variation in the high-frequency impedance of test points as a probe is shifted from point to point influences the samplers and can cause the indicated amplitude and phase errors. These errors are different from the effects of any test-point loading due to the input impedance of the probes.

Phase Accuracy: Within ± 1°, not including phase response vs. frequency, amplitude, and test-point impedance.*

Phase Response vs. Frequency:
1 to 100 MHz: less than ± 0.2°;
100 to 1,000 MHz: less than ± 3°.

Phase Response vs. Signal Amplitude:
1 V to 3 mV rms: less than ±2°;
1 V to 100 μV rms: less than ± 3°
(add an additional ± 10° from 0.1 to 1 V rms between 500 and 1,000 MHz, + for changes affecting channel A only, — for channel B only; effects tend to cancel when signals to both channels change equally).

Phase Response vs. Test-Point Impedance:*
0 to 50 ohms: less than ± 2°;
25 to 1,000 ohms: less than— 0°, + 9° for channel A only, less than + 0°, — 9° for channel B only.

Phase Jitter vs. Channel B Input Level:
Greater than 700 μV: typically less than 0.1° p-p;
125 to 700 μV: typically less than 0.5° p-p;
20 to 125 μV: typically less than 2° p-p.

General

20 kHz IF Output (each channel): Reconstructed signals, with 20 kHz fundamental components, having the same amplitude, waveform, and phase relationship as the input signals. Output impedance, 1,000 ohms in series with 2,000 pF; BNC female connectors.

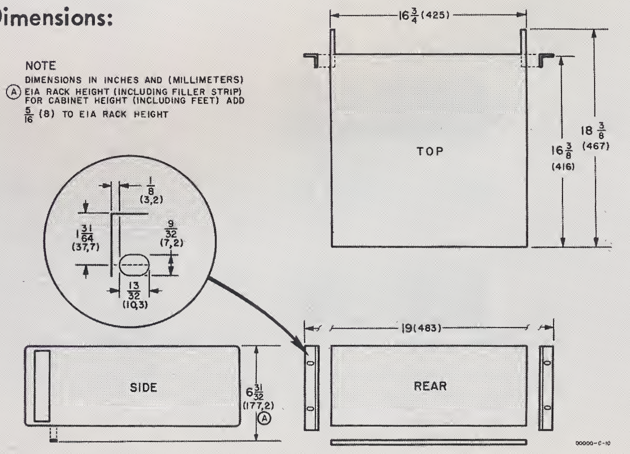
Recorder Output:
Amplitude: 0 to + 1 V dc ± 6% open circuit, proportional to voltmeter reading. Output tracks meter reading within ± 0.5% of full scale. Output impedance, 1,000 ohms; BNC female connector.
Phase: 0 to ± 0.5 V dc ± 6%, proportional to phasemeter reading. External load greater than 10,000 ohms affects recorder output and meter reading less than 1%. Output tracks meter reading within ± 1.5% of end scale; BNC female connector.

RFI: Conducted and radiated leakage limits are below those specified in MIL-I-6181D and MIL-I-16910C except for pulses emitted from probes. Spectral intensity of these pulses is approximately 60 μV/MHz; spectrum extends to approximately 2 GHz. Pulse rate varies from 1 to 2 MHz.

Power: 115 or 230 V ± 10%, 50 to 400 Hz, 35 watts.

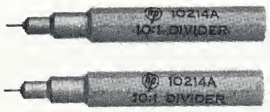
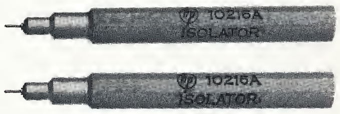
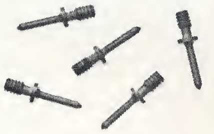
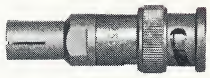
Weight: Net, 30 lbs. *(13,5 kg)*. Shipping 35 lbs. *(15,8 kg)*.

Dimensions:



Price: Model 8405A, $2,500.00.
Model C01-8405A (less 10:1 Dividers), $2,465.00.

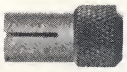
Accessories Furnished

	**10214A 10:1 Divider** (two furnished) for extending voltmeter range. Voltage error introduced is less than $\pm$ 6% 1 MHz to 700 MHz, less than $\pm$ 12% to 1 GHz; if used on one channel only, phase error introduced is less than $\pm (1 + 0.015f/\text{MHz})^\circ$, + for channel A, — for channel B.
	**10216A Isolator** (two furnished) for eliminating effect of test-point impedance on sampler.* Voltage error introduced is less than $\pm$ 6% 1 to 200 MHz, response is 3 dB down at 500 MHz; if used on one channel only, phase error introduced is less than $\pm (3 + 0.185f/\text{MHz})^\circ$, + for channel A, — for channel B.
	**10213-62102 Ground Clip** (six furnished) for 10214A and 10216A.
	**5020-0457 Probe Tip** (six furnished).
	**10218A BNC Adapter** (two furnished) converts probe tip to male BNC connector.

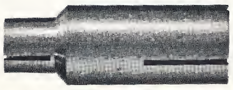
Complementary Equipment

	**774D Dual Directional Coupler,** 215 to 450 MHz, $225.00.
	**775D Dual Directional Coupler,** 450 to 950 MHz, $225.00.
	**8491A (Option 20) 20-dB Coaxial Attenuator,** $50.00.

Accessories Available

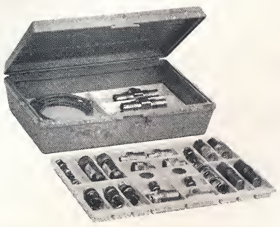


10220A Adapter, for connecting Microdot screw-on coaxial connectors to probes, $3.50.



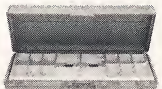
10223A Adapter, for connecting Microdot slide-on coaxial connectors to probes, $2.00.

11512A Shorting Plug, type N male, $4.50.



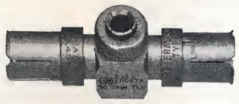
11537A Accessory Kit, includes two each of the following except one each as indicated by**, $379.00.

Each listed item is also available separately.



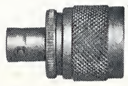
****11529A Accessory Case,** for convenient storage of accessories, includes two compartmented shelves and snap-shut lid, $8.50.

****10503A Coaxial Cable,** 48 in. (1,220 mm) long, BNC male connectors, $6.50.

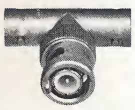


11063A 50-ohm Tee, with GR 874 rf fittings, for monitoring signals in 50-ohm transmission line without terminating the line, $55.00.

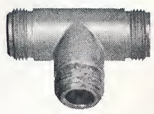
1250-0778 Adapter, both connectors type N male (UG-57B/U), $5.50.



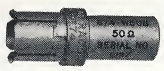
1250-0780 Adapter, type N male and BNC female (UG-201A/U), $3.00.



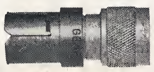
1250-0781 Adapter, Tee, two connectors BNC female, one BNC male, $5.00.



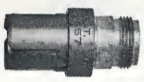
****1250-0846 Adapter, Tee,** all connectors type N female (UG-28A/U), $5.00.



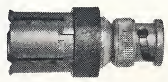
General Radio type 874-W50B 50-ohm Load (also available from HP under part no. 0950-0090, $30.00).



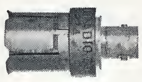
General Radio type 874-QNP Adapter, GR 874 and type N male (also available from HP under part no. 1250-0847, $7.00).



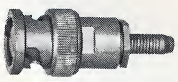
General Radio type 874-QNJA Adapter, GR 874 and type N female (also available from HP under part no. 1250-0240, $6.50).



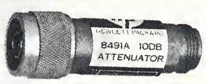
General Radio type 874-QBPA Adapter, GR 874 and BNC male (also available from HP under part no. 1250-0849, $8.50).



General Radio type 874-QBJA Adapter, GR 874 and BNC female (also available from HP under part no. 1250-0850, $6.50).



****10510A 50-ohm Load,** BNC male connector, $5.00.



8491A (Option 10) 10-dB Coaxial Attenuator, $50.00.

Prices f.o.b. factory
Data subject to change without notice